Claims

1. An article comprising a microfluidic channel defined therein designed to have fluid flow therethrough in a principal direction, the microfluidic channel including a channel surface having at least one groove or protrusion defined therein, the at least one groove or protrusion having a first orientation that forms an angle relative to the principal direction.

2. The article of claim 1, wherein the microfluidic channel has at least one of a width and a depth that is less than about 1000 μm.

3. The article of claim 2, wherein the microfluidic channel has at least one of a width and a depth that is less than about 500 μm.

4. The article of claim 3, wherein the microfluidic channel has at least one of a width and a depth that is less than about 200 μm.

5. The article of claim 1, wherein the substrate comprises a polymer.

6. The article of claim 1, wherein the angle is less than about 90 degrees.

7. The article of claim 1, wherein the groove or protrusion has a depth that is less than a width of the microfluidic channel.

8. The article of claim 1, wherein the groove or protrusion has a depth that is less than a depth of the microfluidic channel.

9. The article of claim 1, wherein the groove or protrusion has a width that is less than a width of the microfluidic channel.

10. The article of claim 1, wherein the microfluidic channel includes a first inlet.

11. The article of claim 10, wherein the microfluidic channel includes a second inlet.

12. The article of claim 1, wherein the microfluidic channel has a substantially circular cross-section.

13. The article of claim 1, comprising a plurality of grooves or protrusions formed in the channel surface.

14. The article of claim 13, wherein each of the grooves or protrusions is parallel to each other.

15. The article of claim 14, wherein the parallel grooves or protrusions are periodically spaced along the channel surface to form a first set of parallel grooves or protrusions.

16. The article of claim 15, wherein the microfluidic channel has a width and the first set of parallel periodically-spaced grooves or protrusions traverse the width.

17. The article of claim 13, wherein the channel surface has a second set of parallel periodically-spaced grooves or protrusions traversing at least a portion of the channel surface at a second orientation.

18. The article of claim 17, wherein the second set of parallel periodically-spaced grooves or protrusions are at least partially coextensive with the first set of parallel periodically-spaced grooves or protrusions.

19. The article of claim 17, wherein the first and second sets of parallel grooves or protrusions form a repeating pattern.

20. The article of claim 1, wherein at least one groove or protrusion has at least two sections.

21. The article of claim 20, wherein at least one section is substantially linear.

22. The article of claim 21, wherein the sections intersect to form at least one chevron-shaped groove.

23. The article of claim 22, wherein a plurality of chevron-shaped grooves or protrusions are formed in the channel surface.

24. The article of claim 23, wherein the chevron-shaped grooves or protrusions are periodically spaced along the channel surface.

25. The article of claim 1, wherein a second groove or protrusion is defined in the channel surface, the second groove or protrusion having a second orientation relative to the principal direction.

26. The article of claim 1, wherein the substrate has a network of microfluidic channels fluidly connected to the microfluidic channel.

27. The article of claim 1, wherein the microfluidic channel is formed in a unitary substrate.

28. An article comprising a microfluidic channel constructed and arranged to have a fluid flowing therethrough while creating a transverse flow component in the fluid.

29. The article of claim 28, wherein the microfluidic channel is constructed and arranged so that fluid flowing therethrough has a Reynolds number that is less than about 12.

30. The article of claim 29, wherein the microfluidic channel is constructed and arranged so that fluid flowing therethrough has a Reynolds number that is less than about 5.

31. The article of claim 28, wherein the microfluidic channel has a width that is less than about 1000 μm.

32. The article of claim 28, further comprising a network of microfluidic channels fluidly connected to the microfluidic channel.

33. The article of claim 28, wherein the microfluidic channel is constructed and arranged to create at least one helical flow path in a fluid flowing therethrough.

34. The article of claim 28, wherein the microfluidic channel is constructed and arranged to have a substantially circular cross-section.

35. The article of claim 28, wherein the microfluidic channel is constructed and arranged to have a rectangular cross-section.

36. The article of claim 28, wherein the transverse flow component is created regardless of the Reynolds number of the fluid flowing in the microfluidic channel.

37. An article comprising a structure having a channel defined therein, the channel designed to have a fluid flowing therethrough in a principal direction, the channel including a channel surface having a plurality of chevron-shaped grooves or protrusions formed in at least a portion of the channel surface so that each chevron-shaped groove or protrusion has an apex that defines an angle.

38. The article of claim 37, wherein the angle of the apex is about 45-degrees.

39. The article of claim 37, wherein the channel includes a first set of chevron-shaped grooves or protrusions and a second set of chevron-shaped grooves or protrusions.

40. The article of claim 39, wherein the apex of each of the first set of chevron-shaped grooves or protrusions are aligned offset relative to the apex of each of the second set of chevron-shaped grooves or protrusions.

41. The article of claim 40, wherein the structure comprises a capillary tube.

42. The article of claim 40, wherein the structure comprises a polymer.

43. The article of claim 37, wherein the channel has a width that is less than about 1000 μm.

44. The article of claim 43, wherein the channel has a width that is less than about 200 μm.

45. The article of claim 37, wherein the channel is fluidly connected to a network of microfluidic channels.

46. The article of claim 37, wherein the chevron-shaped grooves or protrusions are periodically-spaced from each other.

47. The article of claim 37, wherein the channel has a rectangular cross-section.

48. The article of claim 37, wherein the channel has a circular cross-section.

49. The article of claim 37, wherein the channel is a microfluidic channel.

50. The article of claim 37, wherein the channel is defined on a unitary structure.

51. A structure comprising:

a first channel having a width that is less than about 1000 μm;

a second channel having a width that is less than about 1000 μm; and

a third channel having a principal direction and a width that is less than about 1000 μm, the third channel connecting the first and second channels and comprising channel surfaces having grooves or protrusions defined therein, the grooves or protrusions oriented at an angle relative to the principal direction.

52. The structure of claim 51, wherein the structure comprises a polymer.

53. A method for dispersing a material in a fluid comprising:

providing an article having a channel designed to have fluid flow therethrough in a principal direction, the channel including a channel surface having at least one groove or protrusion therein that traverses at least a portion of the channel surface, at least one groove or protrusion oriented at an angle relative to the principal direction; and

causing the fluid in the channel to flow laminarly along the principal direction.

54. The method of claim 53, wherein the fluid flowing in the channel has a Reynolds number that is less than about 100.

55. The method of claim 54, wherein the fluid flowing in the channel has a Reynolds number that is less than about 10.

56. The method of claim 55, wherein the fluid flowing in the channel has a Reynolds number that is less than about 5.

57. The method of claim 53, wherein the step of causing the fluid to flow in the channel results in a fluid residence time in the channel of less than about 20 seconds.

58. A method comprising:

causing a first fluid to flow in a channel at a Reynolds number that is less than about 100;

causing a second fluid to flow in the channel at a Reynolds number that is less than about 100; and

creating a transverse flow component in the first and the second fluids to promote mixing between the first and second fluids.

59. The method of claim 58, wherein the channel has a width that is less than about 1000 μm.

60. The method of claim 59, wherein the step of creating a transverse flow component creates at least one helical flow path.

61. The method of claim 58, wherein the second fluid has a Reynolds number that is about equal to the Reynolds number of the first fluid.

62. The method of claim 61, wherein the first fluid has a composition that differs from a composition of the second fluid.

63. A method for forming a microfluidic article comprising:

forming a first topological feature that has a smallest dimension that is less than about 1000 μm on a surface of a mold substrate;

forming a second topological feature on the first topological feature to form a mold master, the second topological feature characterized by a length that traverses at least a portion of a section of the first topological feature;

placing a hardenable material on the surface;

hardening the material thereby creating a molded article having a microfluidic channel shaped from the first topological feature and at least one groove or protrusion shaped from the second topological feature; and

removing the microfluidic article from the mold master.

64. The method of claim 63, wherein the hardenable material comprises a cross-linkable polymer.

65. The method of claim 64, wherein the step of hardening the material comprises applying heat to the material.

66. The method of claim 65, wherein the groove or protrusion has a depth that is less than a width of the first topological feature.

67. A method for producing a helical flow path in a fluid flowing along a principal direction comprising:

providing a structure having a surface with a plurality of substantially linear grooves or protrusions oriented at an angle relative to the principal direction, the grooves or protrusions formed to be parallel to and periodically spaced from each other; and

causing the fluid to flow along the surface, the fluid flowing adjacent the surface having a Reynolds number that is less than about 100.